DOCUMENT RESUME

ED 222 357 SE 039 408

AUTHOR McDermott, Hugh, Ed.; Scharmann, Larry, Ed.
TITLE Energy from the Atom. A Basic Teaching Unit on Energy. Revised.
INSTITUTION Nebraska State Energy Office, Lincoln.
PUB DATE Feb 81
NOTE 35p.; Original writer, R. Doug Martin. For related documents, see ED 179 395 and SE 039 406-416.
AVAILABLE FROM Nebraska Energy Office, Extension Division Chief, P. O. Box 95085, Lincoln, NE 68509 ($5.00).

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Energy; Environmental Education; High Schools; *Learning Activities; *Nuclear Energy; Nuclear Power Plants; *Physical Sciences; *Power Technology; Science Activities; Science Education; *Secondary School Science; *Social Studies
IDENTIFIERS *Energy Education; Nebraska

ABSTRACT

Recommended for grades 9-12 social studies and/or physical science classes, this 4-8 day unit focuses on four topics: (1) the background and history of atomic development; (2) two common types of nuclear reactors (boiling water and pressurized water reactors); (3) disposal of radioactive waste; and (4) the future of nuclear energy. Each topic includes readings (with Fry readability levels for each reading indicated in the introduction) and a follow-up activity which can be used to assess student knowledge of all concepts presented in the unit. Rationale, objectives, and instructional strategies are provided for each activity. A teacher's guide for a slide program on the Fort Calhoun Nuclear Station (available from the Nebraska Energy Office) is included. A list of process skills fostered, advanced teacher preparation, goals, and planning guide are also included in the introduction. (Author/JN)

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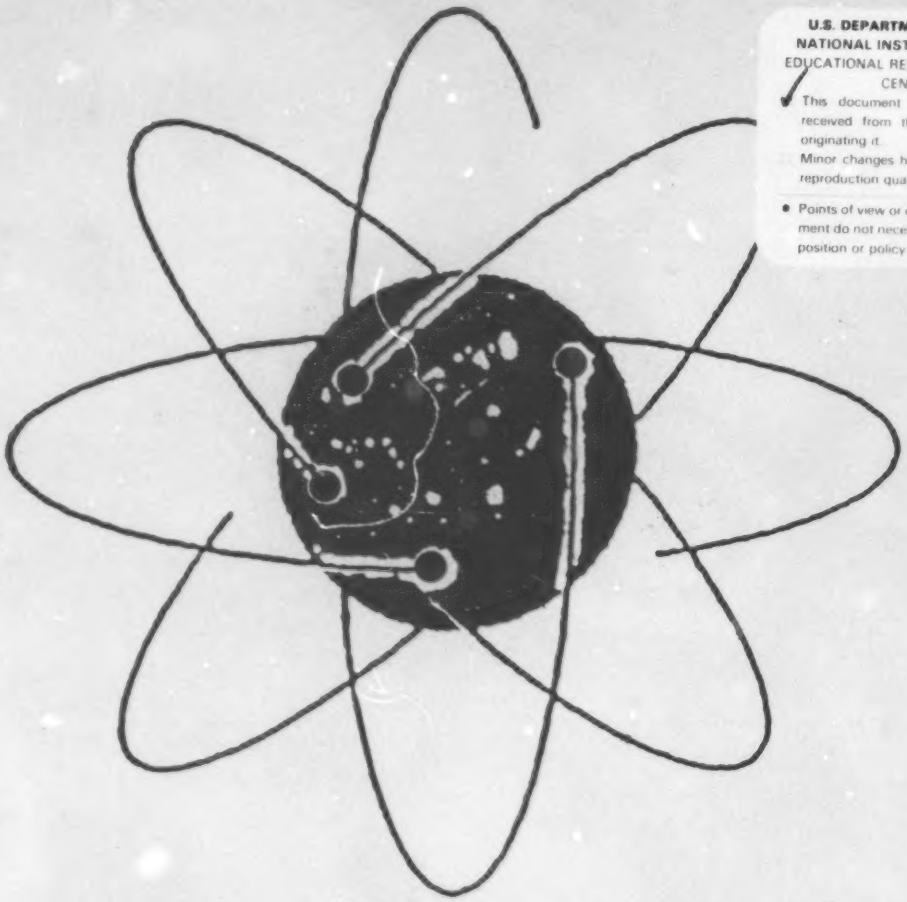

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ENERGY FROM THE ATOM

Edited and Revised by

Hugh McDermott
Larry Scharmann

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A Basic Teaching Unit on Energy

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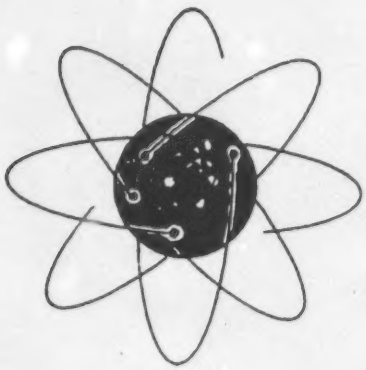
ENERGY FROM THE ATOM



Original Writer:
R. Doug Martin

Recommended Subject: Grades 9-12 Science or Social Studies

TO THE INSTRUCTOR . . .

"Energy From the Atom" contains information relating to the history of nuclear energy and its developmental progression into our modern day society. This unit attempts to explain the concepts of atoms, fission, fusion, the differences between boiling water reactors and pressurized water reactors, how nuclear waste is handled, and the future of nuclear energy.

In addition, there are student readings and activities associated with each topic to obtain student feedback. These activities are, however, optional. You may, therefore, wish to devote more time to those particular sections of the unit you feel most important.

Since material sources continue to change periodically, the source **Energy Info—A Directory of Publications and Audio-Visual Materials From the Nebraska Energy Office,** contains a list of general topics available from the Nebraska Energy Office. You are encouraged to use the ordering page attached to this unit to order additional booklets as well as other energy related materials.

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ACKNOWLEDGEMENTS

The original "Basic Teaching Units on Energy" consisted of a package of 30 instructional packets contained within three volumes. The original fourteen units were written at the University of Nebraska-Lincoln, under the auspices of the Nebraska Energy Office, by Nebraska teachers participating in a three-week Faculty Development Institute sponsored by the U.S. Department of Energy (summer, 1978). The units were edited by the following individuals:

—Dr. Donald McCurdy, Professor of Science Education, University of Nebraska-Lincoln;
—Mr. Gary A. Lay, Education Coordinator, Nebraska Energy Office; and
—Dr. Robert Reeder, Science Department Chairman, East High School, Lincoln, Nebraska.

The present format has been achieved as a result of an evaluation conducted by the Nebraska Energy Office, February, 1981. Rather than continue to offer all 30 units as a single package, the Nebraska Energy Office determined to revise, edit, and typeset the 10-12 highest quality units and continue to offer the other units in their present format.

The editors of these revised "Basic Teaching Units" wish to thank the individual writers, original editors, and clerical staff for their contributions in creating the "Basic Teaching Units".

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Abstract

Fossil fuel resources such as oil and natural gas supplies are limited and increasingly costly. Because of the long term it takes to build a nuclear power plant (about 10 years) and the even longer time it takes to develop new technologies, we have to continue to make some difficult decisions.

This unit provides background material adaptable for physical and social science students wishing to study nuclear power. It focuses on four topics: the background history of atomic development, two common types of nuclear reactors, the disposal of radioactive waste, and the future of nuclear energy. Each of the four readings contains a follow-up activity which can be used to assess student knowledge of all concepts presented in this unit.

There are many additional topics not included which can be explored throughout the unit, such as the use of nuclear power in space, radiation and its effects on humans, and nuclear accidents.

Recommended Level

Grades 9-12

Academic Areas

Science or Social Studies

Readability Ratings (Fry)

The readability level given for each reading below is based on the number of syllables per hundred words and number of sentences per passage. These reading level estimations will allow teachers the opportunity to perform some pre-reading exercises on vocabulary and concept development.

"Everything is Made up of Atoms"—11th Grade
"Nuclear Reactors Today"—11th Grade
"The Disposal of Radioactive Waste"—12th Grade
"The Future of Nuclear Energy"—10th Grade

Time Required

4-8 days

Process Skills

—discussing
—identifying similarities/differences
—interpreting
—reading
—recalling
—writing

Advanced Teacher Preparation

Obtain: Energy Films which may be applicable to a particular activity or unit. The following are available:

NUCLEAR: "To Meet the Challenge"
16mm film
Available from:

Nebraska Public Power District
1414 15th Street
Columbus, NE 68601
402—564-8561

Fort Calhoun Nuclear Station Slide Show and Teacher's Guide, Available from:

Nebraska Energy Office
P.O. Box 95085
Lincoln, NE 68509
402—471-2867
or
The Educational Service Unit
in Your Area

Read: **Energy Info—A Directory of Publications and Audio Visual Materials from the Nebraska Energy Office.**

Goals

When students complete this packet, they should be able to make the following generalizations about nuclear energy:

1. **Most nuclear reactors are either boiling water reactors (BWR) or pressurized water reactors (PWR).**
2. **Nuclear energy has become an important component of our energy future.**
3. **Nuclear energy waste still presents some problems.**
4. **The future use of nuclear energy depends on many present factors and decisions.**

Student Objectives

These are included previous to each activity.

Planning Guide

Day 1
Activity #1, "Everything is Made Up of Atoms"

Day 2
Activity #2, "Nuclear Reactors Today"

Day 3
Activity #3, "The Disposal of Radioactive Waste"

Day 4
Activity #4, "The Future of Nuclear Energy"

Days 5-8
Additional time spent on any of the above activities

Evaluation Suggestions

Evaluation of this unit depends on how each activity is used and is therefore up to the individual teacher.

Instructor Information . . .

Everything is Made Up of Atoms

Rationale:

In order to understand some aspects of nuclear energy, students will need to gain an understanding of the history of nuclear energy and the differences between fusion and fission.

Objectives:

Students will be able to read the article "Everything is Made Up of Atoms."

Students will be able to identify in writing, the differences between fusion and fission.

Students will be able to take a position on nuclear energy and support it.

Implementation:

Have students read "Everything is Made Up of Atoms" either individually or as a class. Either discuss the article orally or move directly into the writing assignment. This assignment attempts to have students organize their thoughts and present them in writing. Students decide whether fusion or fission appears to be more usable for future needs and through their writing, defend that position.

Debriefing:

It might be of interest to have students, supporting either fusion or fission, read their papers aloud and discuss their reasons.

Name _____

Date _____

splitting matter

NUCLEAR

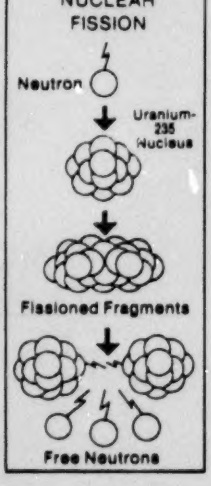
Democritus

meaning of **fission**

uranium

the nucleus of the atom

FUSION



About 2500 years ago Greek philosophers, who were the learned men of their time, thought a great deal about the nature of matter. Some wondered what would happen if a piece of matter—for example, iron—was split into smaller and smaller pieces. Suppose we divided it into halves, then each half was divided into quarters, quarters into eighths, and so on. Could this division go on forever? Or would we eventually come to a piece so very small that it could not be split further?

Some Greek thinkers argued in favor of the first idea, others favored the second. The Greek philosopher Democritus favored the second way. He thought that all material things were made up of small indivisible particles. He called these particles "atoma", which means something that cannot be cut. It is from this Greek word that the English word atom is derived.

The writings of these men concerning atoms did not have much effect during their lifetimes, perhaps because there was so much that was not really understood. A great deal of study was still needed before the idea of atoms could be generally accepted.

In 1803, John Dalton, an English school-teacher, expressed his ideas about atoms. He described the experiments he had made, and other scientists gradually accepted the view that all matter was made up of indivisible atoms.

What Is Nuclear Fission?

The word fission means to split into parts. Nuclear fission is a reaction in which a heavy nucleus is split into two lighter nuclei, each having about the same mass. There are many ways in which nuclear fission can be brought about. Here, the concern is where a neutron is absorbed by and splits the nucleus of a certain isotope of uranium.

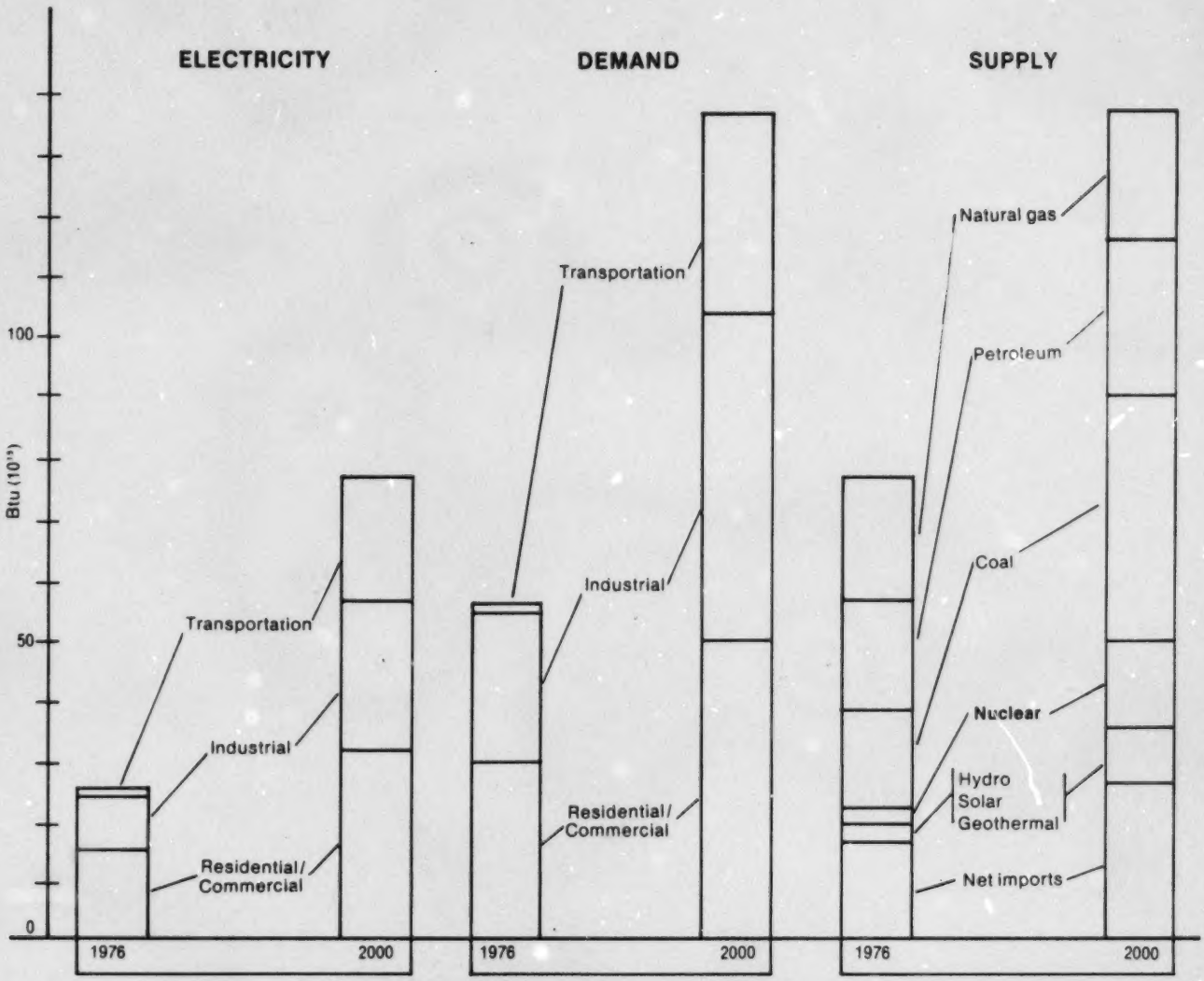
As found in nature, uranium consists almost entirely of two isotopes, uranium-235 and uranium-238. The lighter isotope, uranium-235, is much rarer than the heavier one. It is the uranium-235 nucleus that fissions when it absorbs a neutron.

Nuclear Energy

Soon after radioactivity was discovered at the end of the 19th century, physicists began to conjecture about the energy, which they called "atomic energy", that was apparently stored within the atom. Later, when the nuclear theory of the atom was developed in 1911, scientists realized that it was the nucleus, the central part of the atom, that was the source of this energy. Hence, it is now called "nuclear energy" rather than atomic energy. Until 1932, however, no one knew how this energy could be released in a useful manner.

In the course of his studies in 1905 on the theory of relativity, Albert Einstein showed that mass and energy were, in a sense, equivalent. Consequently, energy should be liberated in any process associated with a net decrease in mass. By considering the measured masses of atomic nuclei, it became apparent that there were two general ways whereby nuclear energy could be made available by using reactions accompanied by a decrease in mass. One is by the splitting (fission) of the heaviest nuclei into nuclei of intermediate mass, and the other is by the combination (fusion) of some of the lightest nuclei. Actually, there are many other nuclear processes that are accompanied by a liberation of energy. But only with nuclear fission and fusion is there the possibility of producing more energy than is consumed during the reaction. In other words, only for these reactions is there a prospect that the process once started can be self-sustaining like a fire.

The discovery of nuclear fission in 1932 revealed a new and highly concentrated source of energy. Some six years later this energy was first used in the atomic bomb, and since that time nuclear reactors have been developed in which fission energy is liberated as heat and converted into electric power. The impact of nuclear fission energy is already being felt in many countries. But fission is not the complete solution to the energy problem. It is true that the world resources of the basic materials, namely uranium and thorium minerals, are fairly abundant. There are, however, many countries that either do not possess these minerals or do not have the means for producing nuclear fuels from them. Furthermore, special precautions must be taken in the operation of fission power plants to prevent undesirable environmental effects.



EPRI forecasts U.S. energy demand will reach approximately 130 quadrillion (10^{15}) Btu by the year 2000, with coal and nuclear—delivered in the form of electric power—assuming an increasing role. As presently foreseen, the supply gap will have to be filled by imported energy.

Everything is Made Up of Atoms

Activity 1,
Student Worksheet, Page 1

Directions: Based on the information you read in "Everything is Made Up of Atoms", explain in writing, the difference between fusion and fission. Also, take a particular side as to what you believe would be the more useful alternative for future use. Explain the reasons for your position.

Instructor Information . . .

Nuclear Reactors Today

Rationale: There are basically two types of nuclear reactors operating to produce electricity in the United States. This reading explains the differences between the boiling water reactor (BWR) and the pressurized water reactor (PWR).

Objectives: Students will be able to read "Nuclear Reactors Today."

Students will be able to answer questions concerning the boiling water reactor and the pressurized water reactor.

Implementation: Hand out the article entitled "Nuclear Reactors Today" to read. Have students answer worksheet questions concerning this reading.

Debriefing: It may be useful to have students work in pairs to complete the worksheets. This strategy allows them to work together in paraphrasing their answers.

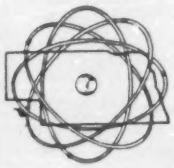
Nuclear Reactors Today

Activity #2, Page 1

Name_____

Date_____

nuclear power's influence



Nebraska: 50% nuclear power

boiling water reactors

self limiting

slowing the reaction down

steam turns the turbine

NUCLEAR FUEL PELLET
A single pellet of nuclear fuel contains as much energy as a ton of coal.

slowing down and speeding up the nuclear reaction

In a world of constructed energy options, nuclear power is one of the few expandable, domestic resources. In just 25 years, it has established itself as a major contributor to the base-load supply of electricity in the more industrialized regions of this country. Nuclear power has made its biggest penetration in areas dependent upon imported oil and distant sources of low-sulfur coal. The roughly 70 operable nuclear power reactors account for 9.5 percent of the nation's electric-generating capacity and more than 11 percent of the actual power production. When all of the 115 reactors still under construction or on order are completed, nuclear power's share of the nation's electric capacity will be close to 20 percent. Regionally, nuclear energy's impact is even more dramatic than the national share: more than 30 percent of electric generation in Wisconsin, Maryland, Arkansas and South Carolina is nuclear; in Nebraska and Connecticut, it is about 50 percent; in Maine, 65 percent; and in Vermont, 79 percent. Fully 38 percent of the electricity supply in the New England region is nuclear.

Many of these reactors are like the Cooper Nuclear Station, two miles south of Brownville, Nebraska, along the Missouri River. This plant has a boiling water reactor (BWR) generating unit with a capacity of 800,000 kilowatts. The boiling water reactor has the inherent characteristic of being self limiting. As the reactor heat output increases, steam bubble formation increases, water volume decreases and power output is limited. This is because the water circulating through the reactor serves as a moderator much like the graphite blocks in Fermi's "atomic pile". A moderator slows down neutrons so they are more apt to stay in the area where they can strike more U-235. If the reactor heat increases, causing more bubbles, the water becomes less of a moderator and some neutrons fail to strike U-235 atoms to continue the reaction to slow down therefore producing less heat. Because of this, a plant operator can quickly change the power level of a BWR, not only by manipulating the control rods (Fermi's cadium rods), but also by regulating the flow of water into the reactor core. These self-regulating characteristics make it impossible for this type of reactor to "run away". Accordingly, the BWR has been accepted by the nuclear industry and by the Atomic Energy Commission as inherently safe and reliable.

The diagram on page 10 shows the basic boiling water reactor steam cycle used at the Cooper Nuclear Station.

The water circulating inside the reactor is turned to steam by the heat of the core. This steam travels to and turns the turbine thus producing electricity in the generator. After traveling through the turbine, the steam is condensed back into liquid by loops of pipe in the condenser. The loops of pipe have cool water from the Missouri River circulating through them. Next, the condensed water is pumped back into the reactor.

The uranium fuel core is composed of uranium dioxide pellets about the size and shape of cigarette filters, stacked in sealed metal tubes 12 feet long. Bundled together, these fuel rods make up a fuel assembly, in turn arranged in a carefully designed pattern to form the fuel core of the reactor. The core of the Cooper Nuclear Station contains 548 fuel assemblies. Periodically, some of the fuel assemblies must be replaced and others moved, since assemblies toward the center encounter more neutrons and are depleted faster.

Interspersed among the fuel assemblies are the control rods. These cadium rods have the ability to absorb neutrons and thus slow down or speed up the nuclear reaction. These control rods are a means of shutting down the reactor if needed.

Additional control mechanisms are designed into the reactor to assure its safety during normal operation and to provide several independent monitoring and control systems for rapid shutdown if a predetermined safety limit should be exceeded. These engineering safeguards are fully automatic and do not require initiation by plant operators. And even though they are not expected to be used during the plant's lifetime, they are built according to the most stringent design criteria. From the beginning, the nuclear industry has been the first to consider safety as a primary concern. With the most cautious approach in engineering history, the nuclear power industry has achieved one of the finest records in the field of industrial safety.

Multiple physical barriers designed into a nuclear power plant prevent the release of radioactive substances in the unlikely event of an accident. These safeguards do not depend

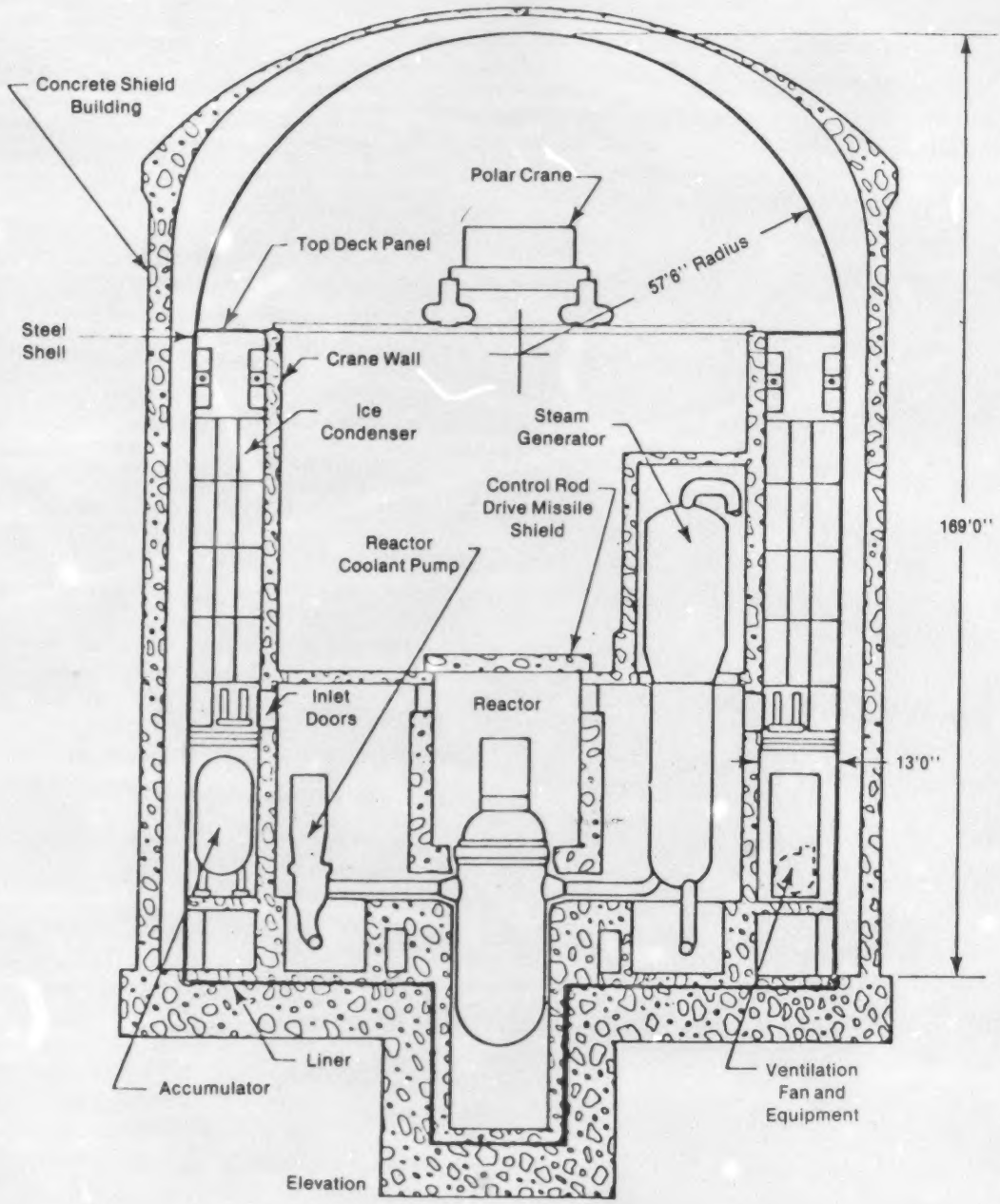
on the operation of any complex equipment; their passive physical presence alone guarantees their function. First, there is the natural tendency of uranium to hold stubbornly onto its fission products. Then there is the fuel element cladding—zirconium alloy tubes half an inch in diameter and 12 feet long—whose walls serve to contain the radioactive substances. Water surrounding the fuel core also captures part of any fission products that might escape. Next, there is the reactor vessel itself which must be breached before radioactive materials can escape. The walls of this 70 foot high welded steel tank are about 6 inches thick. Finally, an overall containment system encloses the entire reactor pressure vessel. With the BWR used at the Cooper Nuclear Station, the entire nuclear steam supply system is contained in a steel tank which is a 7/8 inch thick structural steel vessel. It is constructed somewhat like a light bulb with the bulb portion being 65 feet in diameter. Below the containment and also part of the primary containment system, is the torus which is made of a doughnut shape. The overall diameter of the torus is 135 feet and the diameter of the doughnut itself is 29 feet. This is surrounded by a radiation shield of reinforced concrete, several feet thick. In the unlikely event of an equipment breakdown—such as a pipe rupture—any escaping steam would be immediately condensed in a giant pool of water spray systems. Temperature and pressure could not build to dangerous levels. Also, in bubbling through the water, any steam would be scrubbed essentially free of solid radioactive products. There is still another barrier surrounding the primary containment system and that is the entire reactor building containing more than 90,000 cubic yards of concrete and tons of steel to provide additional protection against the release of fission products. With this series of multiple protective barriers, radiation at the plant site boundary would remain at safe levels even in the unlikely event of a major nuclear accident. The diagram below shows these safety features.

preventing radioactive release

thick surround-ings

temperature and pressure

PRESSURIZED WATER REACTORS



CROSS-SECTION OF A PWR CONTAINMENT BUILDING

The containment building has the entire primary system, as well as various safety systems, in its interior. The building itself is concrete, with a steel shell inside. The safety systems within the building include emergency core cooling systems (note the accumulator), pressure control systems (one form of which may be the ice condenser indicated), and ventilation equipment. (Figure courtesy of Westhinghouse Electric Corp.)

Name_____

Date_____

Directions: Answer the following questions after reading "Nuclear Reactors Today".

1. How much electric nuclear generation is presently generated in Nebraska?

2. The boiling water reactor has the inherent characteristic of being self limiting. Explain.

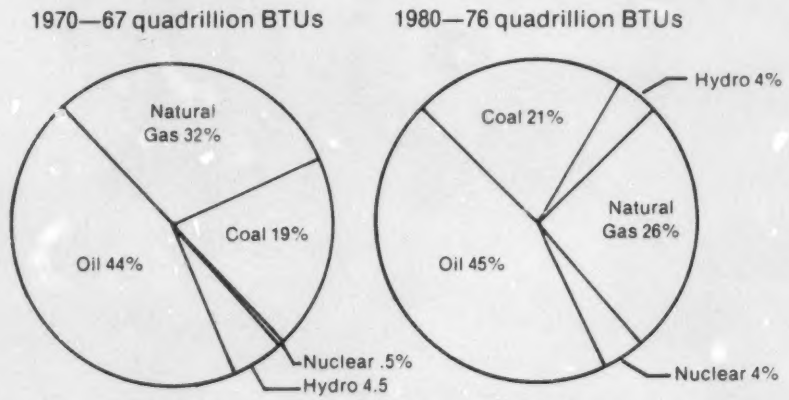
3. Explain what happens in the process of changing water to electricity.

4. Why do some of the fuel assemblies need to be replaced or moved once in a while?

5. Describe **one** safeguard built into the design of a nuclear power plant.

6. What is the difference between the boiling water reactor and the pressurized water reactor?

Figure 1: Energy Consumption in the United States



Source: Energy Information Administration: 1980 Annual Report to Congress, Volume Two Data

Instructor Information . . .

The Disposal of Radioactive Waste

Rationale: There are several options in storing spent fuel. Whatever method is used requires rational decision making. This activity contains information on spent fuel storage, the managing of high level waste, and radiation exposure.

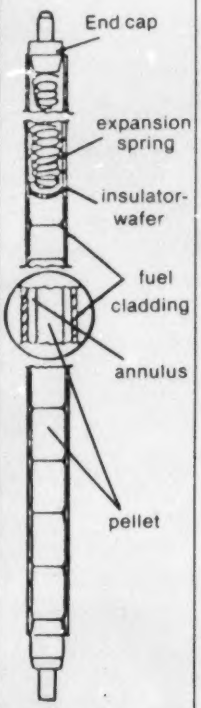
Objectives: Students will be able to read the article "The Disposal of Radioactive Waste".

Students will be able to orally discuss what other alternatives are available for storing nuclear waste.

Implementation: Hand out and read "The Disposal of Radioactive Waste". Through an oral discussion examine other possible ways of storing nuclear waste.

Debriefing: The variety and reasons supplied in the discussion will provide some indication of student interest in the topic.

Nuclear fuel management

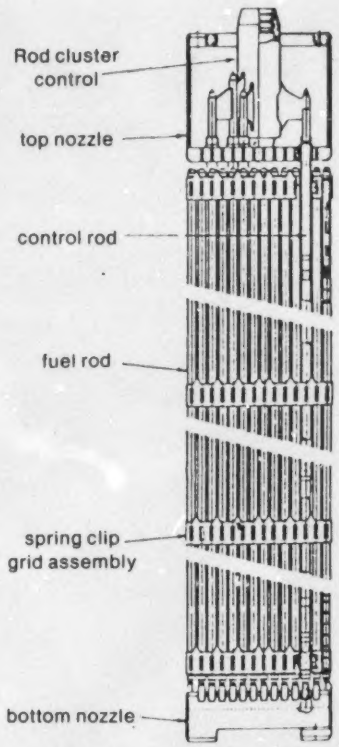


reactor storage capacity

proposed government storage services

Spent Fuel Storage

At a nuclear power plant, from one-fourth to one-third of the uranium fuel core is replaced each year. That spent fuel is removed—contained in square assemblies of rods some 14 feet long by one-half inch in diameter—is stored initially at the reactor site in water-filled pools of reinforced concrete lined with stainless steel. As traditionally envisioned, this spent fuel would be transported after several months' cooling to reprocessing plants for recovery of residual uranium and newly generated plutonium. On April 7, 1977, however, commercial reprocessing in the U.S. was deferred indefinitely as part of a presidential policy to reduce the risk of nuclear weapons proliferation. As a result, reactor water basins now must be modified to store not relatively small amounts of spent fuel for several months, but much larger quantities for several years.



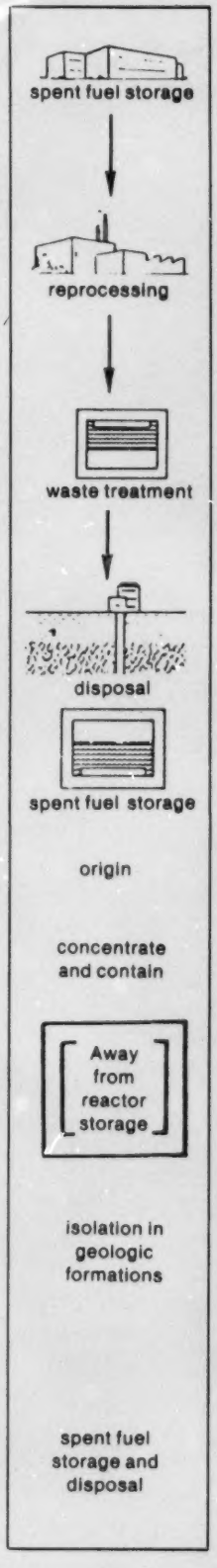
To meet this need, utilities already have taken steps to expand on-site storage capacity. At plants under construction or planned, future water basins may be enlarged in the design stage. At plants currently operating, additional or improved storage racks have been installed to utilize all available space in order to increase the density of fuel assembly loading. Spent fuel also can be transferred to other pools at multiple unit sites or, after sufficient cooling, at similar reactors on the same utility system. These modifications typically extend the capacity of existing basins to 10-15 annual fuel discharges. Even these utility initiatives, however, will prove insufficient if the suspension of reprocessing is prolonged and if off-site storage capacity is not made available.

On October 18, 1977 the Department of Energy proposed a program under which utilities could transfer title and custody of spent fuel to the federal government upon payment of a fee and delivery to an approved storage site. DOE intends ultimately to store irradiated fuel assemblies in geological formations suitable for permanent disposal if reprocessing does not occur. This repository is targeted to begin operation in the early 1990s. Until that time, DOE plans to provide capacity for interim storage of spent fuel at away-from-reactor (AFR) water basins built and managed by private industry or, if necessary, by the government. In February

of this year, DOE transmitted to the President and Congress a proposed Spent Nuclear Fuel Act of 1979 and a proposed bill for Nuclear Regulatory Comission licensing of AFR's built for storing commercial nuclear fuel. DOE intends to recover from utilities all costs associated with storage and disposal of spent fuel. Estimated fees for accepting a typical annual fuel discharge range from $4.5 million to $7.5 million, in 1977 dollars, or up to 8 percent of current costs for nuclear generation. If reprocessing eventually is approved, utilities could reclaim title together with a partial refund of fees or a credit for managing future solidified high level waste. If reprocessing is denied, no compensation is offered for the value of residual uranium and plutonium. Preliminary guidelines proposed by DOE require five years' advance notice to transfer title. Spent fuel, therefore, could not be accepted at a federal storage facility before 1984—the target date for completing the first AFR.

By that time, much of the expanded capacity gained at reactor basins through utility modifications will have been filled. With pools unable to accept spent fuel assemblies from annual discharges, refueling of the nuclear generating station could not take place. In these cases only transfers of spent fuel to other storage facilities on the same system will prevent these plants from shutting down.

It is essential, then, that DOE maintain, and if possible accelerate, its schedule for providing off-site capacity for interim storage of spent fuel. A necessary first step is the prompt formulation of a firm structure of fees, time and method of payment and detailed criteria for accepting title to spent fuel. Only with these guidelines can utilities determine the feasibility and economics of transferring discharged fuel assemblies to the government. In turn, this assessment will enable private industry to propose providing storage facilities as needed. Continued operation of nuclear power plants already on line, as well as utility confidence in ordering additional nuclear generating capacity, depends on the earliest possible resolution of the spent fuel storage problem.



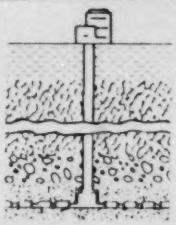
Managing High Level Nuclear Waste

More than 99 percent of all the radioactivity produced by waste in the entire fuel cycle for a nuclear power plant is contained within the assemblies of spent fuel it discharges each year. By-products of the fission process, this annual waste from the reactor weighs less than one ton. Containing and isolating this material from man and the environment until its radioactivity has decayed to harmless levels is the objective of a nuclear waste management program.

Reprocessing the spent fuel to recover remaining energy values would produce a concentrated liquid waste. This residue is converted first to dry powder or granules, then melted to monolithic glass within stainless steel canisters, 14 inches in diameter by 10-12 feet long. All the fuel discharged by commercial nuclear power plants to the end of the century, if reprocessed, would fill approximately 36,000 waste containers, occupying some 425,000 cubic feet.

Solidified and encapsulated, high level waste is suitable for isolation—separation from the biosphere over the time necessary for radioactive decay. For the past two decades, permanent disposal in deep geologic formations has been extensively studied, with bedded deposits of rock salt identified as the most promising medium for a repository for the permanent disposal of solidified commercial nuclear waste.

With reprocessing deferred indefinitely, however, this repository now must be capable of accepting also spent fuel assemblies for retrievable storage or permanent disposal. Most of the technologies, materials and methods developed for canisters of glassified waste apply also accepting spent fuel assemblies for retrievable storage or permanent disposal. Most of Several times as many containers are required, however, with a corresponding increase in total volume: more than 300,000 packages occupying up to 3,225,000 cubic feet for cumulative discharges to the turn of the century. Further, spent fuel generates slightly more heat and over a much longer period than does solidified reprocessed waste. And it contains 100 times more long-lived plutonium. The effects of these incremental impacts on geological medium and facility design have not been fully assessed for a repository for storage and disposal of intact spent fuel assemblies.



federal repository

radiation effects

exposure standards

man-made and natural radiation

medical industrial scientific radiation

In March, 1978, the President established an Interagency Review Group of Nuclear Waste Management to "formulate recommendations for establishment of an administration policy with respect to long-term management of nuclear waste and supporting programs to implement this policy." The result of this effort is a draft report to the President issued by the IRG in March, 1979. Major decisions on the federal program for nuclear waste management now await a presidential review memorandum.

Radiation Exposure

Another area of concern is exposure to radiation. Radiation standards for the public are set far, far below the levels of exposure at which any biological injury has ever been known to occur. At extremely high doses, radiation can harm the human body. This effect may be directly to the individual exposed (somatic) or to his offspring through damage to reproductive cells (genetic). Convincing evidence that radiation bears a cause and effect relationship to somatic effects in man, such as cancer or leukemia, is found only above total doses of 100,000 millirems (a millirem is a standard measurement for biological effect of radiation).

For individual members of the public, including those in the vicinity of a nuclear power plant, the maximum permissible exposure is 500 millirems per year. For large groups of the general public, regardless of location, the maximum permissible exposure is 170 millirems per year. The average citizen of the United States receives about 225 millirems of radiation per year from natural and man-made origins independent of the nuclear energy program. Man has always been surrounded by a sea of naturally occurring radiation. About 40 millirems annually come from cosmic rays penetrating the earth's atmosphere. This exposure varies widely from place to place due to reduced shielding at higher altitudes. Living atop a 400 foot hill, for example, results in approximately five millirems more than living in the valley below.

In addition to natural sources, man receives radiation from everyday medical, industrial and scientific activities. The average American is exposed to 90 millirems annually from medical diagnosis and treatment. Fallout from past atmospheric testing of nuclear weapons gives another four millirems. Consumer products such as television sets and luminous dial clocks and watches contribute a further one millirem per year. In comparison, the average annual exposure to the entire population from all nuclear generating stations now operating is about 1/1000 of one millirem.

ENERGY COMPARISONS

The nuclear energy released from 1 pound of plutonium is equivalent to the chemical energy that can be obtained from 3,000,000 pounds of coal (enough to fill 25 railroad cars).

ANNUAL RADIATION EXPOSURE TO U.S. POPULATION

	Dose		Statistical Projection	
	Average (mrem)	Total (person-rem)	Cancer	Genetic Defect
Source				
Natural background	100	21,700,000	3,050	193
Technologically enhanced*	5	1,000,000	150	10
Medical diagnostics	85	18,500,000	2,600	164
Nuclear power (general public)**	0.03	6,000	1	0.05
Nuclear power (workers)	600	33,000	5	0.3
Nuclear weapons (development and fallout)	6	1,400,000	200	13
Consumer products	0.03	6,500	1	0.06
Effects				
Total from all radiation sources			6,007	381
Total from all causes, known and unknown			400,000	356,000
Percent from all radiation sources			15%	0.1%

Note: Calculations by Ralph Lapp, based on estimates of the BEIR committee.

*Mainly from naturally occurring radionuclides redistributed by human activities, such as mining and milling of phosphate and burning coal.

**Assuming normal operation, normal exposure. The radiation from the TMI accident (50-mile radius) was 1.5 mrem, 3,300 person-rem, expected to produce 1 cancer, 0.05 genetic defect.

Instructor Information . . .

The Future of Nuclear Energy

Rationale:

If students have some idea concerning nuclear energy's present capacity and the factors which influence future predictions, they will be able to recognize nuclear's possible potential.

Objectives:

Students will be able to read "The Future of Nuclear Energy."

Students will be able to identify reasons for using and not using nuclear energy.

Students will be able to defend their choices in writing.

Implementation:

Have students read "The Future of Nuclear Energy." Hand out student worksheet and have students record reasons for and against using nuclear energy in the future. Then have students choose any three of the six reasons and defend their choices by writing an essay.

Debriefing:

You may want to have students focus on particular writing skills. Also, it is acceptable for students to choose reasons from both columns.

Name _____

Date _____

From the end of World War II, utilities were observing a nationwide annual growth in electricity demand that consistently exceeded 6 percent. This trend was not expected to subside, and as the total national generating capacity grew, larger and larger amounts of new capacity would be required to meet this demand growth. From 1970 through 1974 utilities placed orders for 145 reactors with a capacity totaling nearly 160 gigawatts (GWe). A gigawatt is equivalent to one million kilowatts (KW) or one thousand megawatts (MW) . Of these orders, 68 were later cancelled as demand growth dropped, construction costs escalated, and regulatory uncertainties made reactor projects more problematic to complete. Between 1975 and 1978, only 13 orders were placed and 10 of these were later cancelled. No orders have been made since 1978, and none are anticipated in the near future.

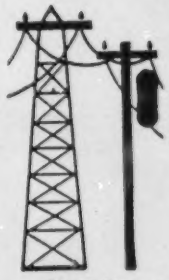
Although there have been a number of delays and cancellations of nuclear units since 1974, nuclear power continued to grow until 1979 in terms of more capacity, high generation, and larger shares of total nationwide electricity production. In March, 1979, the Three Mile Island-2 reactor was severely damaged by an accident involving loss of cooling water. Following the accident, the NRC halted licensing for operation and construction and issued a number of short-term requirements involving both procedural and equipment changes.

By the end of 1985, nuclear power capacity is projected to generate 18 percent of the total U.S. electricity. By the end of 1995 this capacity could generate 21 percent of total electricity.

These projections are vulnerable to a number of uncertainties. The major uncertainty for the 1985 projection is the time required to complete units that are now in advanced stages of construction. This may be influenced by new safety regulations (such as those stemming from the accident at Three Mile Island). Additional sources of uncertainty for the 1990 forecast, that will influence units in early phases of construction include: demand growth, the ability to finance, and the desire to continue projects in light of the unwillingness of state public utility commissions to grant additional rate relief. Additional sources of uncertainty for the 1995 forecast include licensing times for new construction, siting regulations, and resolution of the nuclear waste disposal issue. In considering these factors, by 2010 nuclear power could supply over 30 percent of total generation.

In summary, the long-term projections imply that electricity demand will continue to increase albeit at reduced levels corresponding to lower expectations for growth in the general economy and improvements in the efficiency of energy utilization. Along with coal-fuel technologies, and barring unforeseen political and technical constraints, nuclear power could economically serve a major portion of future demand for central station power production.

growing electrical demand



electricity

no new orders

nuclear power grows

licensing is halted

future projections

What We Use To Make Electric Energy:

Coal 48%
Gas 15%
Hydro 12%
Nuclear 11%

Nuclear Power in the World

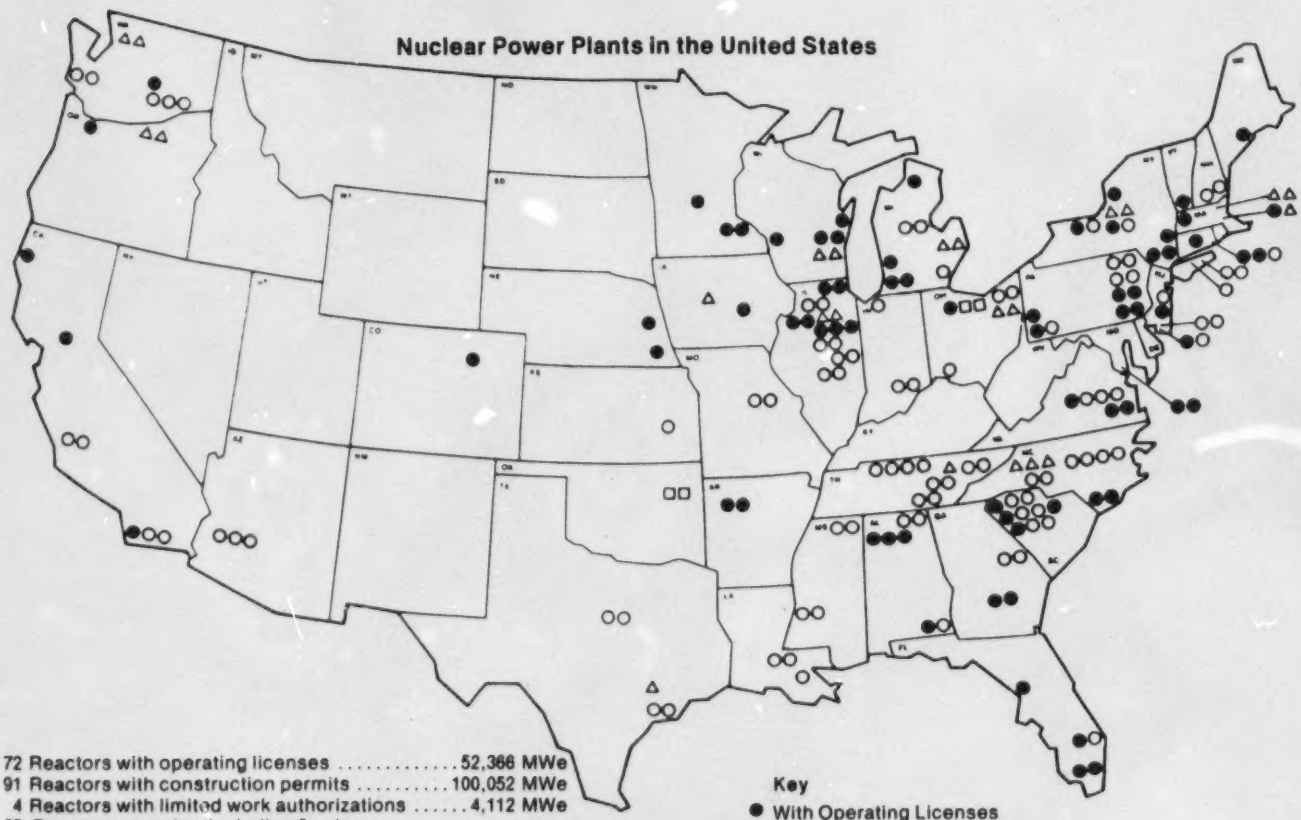
Today world energy consumption is approximately 300 quads (the U.S. uses 77 quads or 26% of the world total). In the year 2000, it is projected that the world will need 520 quads assuming a population of 7 billion. Third World countries are developing, and in order for them to develop they will require large quantities of energy. Thus, the marketplace is becoming very competitive for energy and affects us here in Nebraska as well. Oil and gas supplies are limited and some countries are not as fortunate as the U.S. to have large coal supplies. Thus, some countries have few choices except to develop nuclear energy. Are countries other than the U.S. doing this? The table lists the countries and the number of plants operable, under construction or on order.

World List of Nuclear Power Plants

Operable, under construction, or on order (30 MWe and over) as of December 31, 1978

Country	Number of Power Plants	Country	Number of Power Plants	Country	Number of Power Plants
Argentina	2	Hungary	4	Poland	1
Austria	1	India	8	Rumania	2
Belgium	7	Iran	4	South Africa	2
Brazil	3	Italy	9	Spain	17
Bulgaria	4	Japan	28	Sweden	12
Canada	24	Korea	5	Switzerland	7
Czechoslovakia	5	Libya	1	Taiwan	6
Egypt	1	Luxembourg	1	United Kingdom	39
Finland	4	Mexico	2	United States	195
France	51	Netherlands	2	USSR	36
Germany, East	7	Pakistan	1	Yugoslavia	1
Germany, West	29	Philippines	2		

Totals:	Units	Megawatts Electric
Non-U.S.	328	215,364
U.S.	195	189,604
World	523	404,968

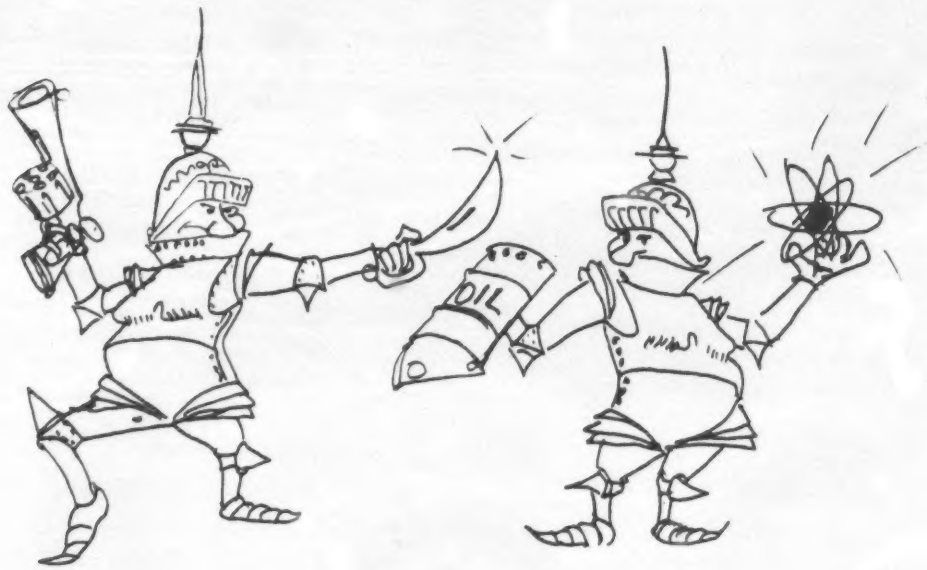

Nuclear Power Plants in the United States
72 Reactors with operating licenses ..... 52,366 MWe
91 Reactors with construction permits ..... 100,052 MWe
4 Reactors with limited work authorizations ..... 4,112 MWe
25 Reactors on order (including 2 units not sited on map) ..... 29,094 MWe
192 Total ..... 185,624 MWe
January 1, 1980
Key
With Operating Licenses
With Construction Permits
Limited Work Authorizations
On Order
Letters of Intent/Options

It is interesting to note that even Middle East countries with large oil reserves are on the list. With or without nuclear power, the potential for proliferation of nuclear weapons cannot be stopped. Much easier methods exist for obtaining these materials, e.g., laser isotope separation or physic machines called mass separators can be easily built or purchased.

If nations do not use fission and fusion for energy generation, then they may risk using it in other than a peaceful manner in the search for other supplies of energy as a result of society unrest. Why? Because society would not accept the risks of utilizing nuclear power for energy needs at the onset of the energy problem.

the danger of nuclear weapons

risk factors



The Future of Nuclear Energy

Activity #4, Page 1
Student Worksheet

Name_____

Date_____

Directions: Write down three reasons **for** using nuclear energy in the future. Then write down three reasons **not** to use nuclear energy in the future. Now, choose any three and explain your reasons for these choices.

Reasons for using nuclear energy

1. _____

2. _____

3. _____

Reasons for not using nuclear energy

1. _____

2. _____

3. _____

Essay

Instructor Information . . .

The Fort Calhoun Nuclear Station Slide Presentation

Today, there are 76 nuclear power reactors operating in this country. Another 81 reactors have construction permits, with more than a dozen virtually completed and awaiting only operating licenses.

But in the aftermath of the March, 1979 accident at Three Mile Island, nuclear power supply hasn't been moving ahead as rapidly as it was a decade ago.

And delays in construction, obtaining permits and certification have added enormously to the cost of completing a power generating plant and placing it in service.

Even so, nuclear plants provided nearly 11 percent of the electrical generating capacity of the United States in 1980.

Ten years from now, electricity generated from nuclear power could match the output that would otherwise require more than four million barrels of oil each day. That would help the United States become less dependent on expensive and uncertain supplies of imported oil.

What is Nuclear Energy, Anyway?

Nuclear energy is used to generate electricity. In the process, nuclear fuel—primarily uranium—is used instead of conventional coal, oil or natural gas to change water into active steam. As atoms split apart in a controlled reactor, enormous quantities of heat are released. This heat creates the steam that drives the turbines which produce millions of kilowatts of electricity.

The Fort Calhoun Nuclear Station

I. **Introduction**

This slide program allows you to take a visual guided tour through the Fort Calhoun nuclear power plant. It was designed as a media supplement to the **Basic Teaching Unit,** "Energy From the Atom." It may also be used in a comparative sense with the **Basic Teaching Unit,** "Coal: Fuel of the Past, Hope of the Future." This particular slide presentation is approximately 30-45 minutes in length.

A. **Purpose Statements**
1. To introduce students to a visual display of a nuclear power plant.
2. To have students observe the basic components of the nuclear power plant.

B. **Objectives**
After viewing the slide series, the student will be able to:
1. identify the major features of a nuclear power plant; and
2. discuss the problems associated with the construction and operation of this type of power generating facility.

C. **Provocative Questions**
1. **What are the five principal structures of this plant?**
Containment building (round building), auxiliary building, turbine building, service building, and water intake structure by river.
2. **What type of fuel is used in the reactors?**
Uranium pellets.
3. **What happens to the water used from the Missouri River?**
The water is returned to the river with some temperature change.
4. **What is the steam used for in the process?**
The steam is used to run the turbines which in turn rotate the generators.
5. **To what areas of the country does this electricity then travel?**
The transmission line connects with lines extending from Kansas City through eastern Nebraska and north to Minneapolis.

Instructor Information . . .

D. **Available Resources**
Should you or your students wish to follow up this program, the following types of resources are available from the Nebraska Energy Office:

1. **Brochures**
   a. Energy—Do We Need Nuclear Power?
   b. Energy Info. . .A Directory of Publications and Audio-Visual Materials from the Nebraska Energy Office
   c. Energy technology
   d. Nuclear Power in Space

2. **Activity Packets**
   a. Basic Teaching Unit "Energy From the Atom"
   b. Basic Teaching Unit "Coal: Fuel of the Past, Hope of the Future"

3. **Human**
   Public Information Officer
   Fort Calhoun Nuclear Power Station
   Omaha Public Power District
   1623 Harney Street
   Omaha, NE 68102

E. **Essential Advanced Preparation**
1. Slide carousel and projector
2. Read BTU "Energy From the Atom" and other available resources

Instructor Information . . .

Narrative for Slides of Fort Calhoun Nuclear Station

1. The Fort Calhoun Station is a nuclear plant designed to produce 481 electrical gross megawatts of electricity. The site is about 19 miles north of Omaha in Washington County.
2. It is located on a 382 acre site on the west bank of the Missouri River.
3. Many sampling studies were conducted by biologists prior to and during construction (hoop netting, bag seining, telephone shocking, benthic sampling).
4. The U.S. Corps of Engineers maintains the channel width (at 600 ft.) and bank by rock filling and pile replacement.
5. Limnology was just one part of the extensive research conducted.
6. Animal populations (mice) were monitored prior to, during and after construction.
7. In construction, 108,000 cubic yards of earth were moved, and 1,851 tubular foundation piles driven.
8. Many other materials were used including 6,200 tons of reinforcing steel.
9. The steam generators were delivered by barge.
10. Same as (9).
11. The reactor (39' tall, 140'' wide and weighing 558,000 lbs.) is put in place.
12. Same as (11.)
13. The plant consists of five principal structures: the containment building (round building), auxiliary building (right of containment building), turbine building (large square building), and service building. All are connected. Lastly, you can see the separate water-intake structure by the river.

Instructor Information . . .

14. Pressurized Water Reactors (PWR) operate with two coolant loops: a primary reactor loop and a secondary turbine-generator steam loop. The secondary power loop is expanded through the turbine to drive the generator; exhaust steam from the turbine is then condensed by river water and pumped back to the steam generator.
15. This door leads to the containment building which houses most of the nuclear components of the facility.
16. The reactor is housed in a containment building which has a ¾'' leak-tight carbon steel liner over steel reinforced concrete walls nearly 4 feet thick.
17. Looking down into the reactor vessel.
18. The uranium pellets are placed in tubes (rods) clad with zirconium. Each pellet is equal to 2,400 pounds of coal. These rods are placed together in fuel assemblies.
19. There are 176 rods in each fuel assembly and 133 assemblies in the reactor core.
20. The fuel storage in the plant.
21. The blue light given off is due to the electrons traveling faster than the speed of light.
22. Record keeping for spent and new fuel storage.
23. Emergency core cooling system spray lines.
24. Incoming steam lines to the turbine building.
25. Turbine room showing moisture separator.
26. Generator with turbines (high and low pressure).
27. The generator (square box) produces 455,000 kw. The two turbines operate at 1800 rpm.
28. Water intake building. Water is taken in from the Missouri River and circulated at approximately 360,000 gallons per minute through the stainless steel tubes in the condensor.
29. Gauge showing water level of the Missouri River.

Instructor Information . . .

30. Water returns to the river. The safety criteria allows a 5 degree F. change for the period May through October and 10 degress F. change for the period November through April The maximum limit is 90 degrees F. and the maximum rate of change is limited to 2 degrees F.

31. The warmer water is dispersed down the Missouri River.

32. Throughout the plant, there are radioactive monitoring devices.

33. Those devices are in constant operation.

34. Whole body counters are used to check people for radiation levels as they leave an area.

35-37. The control room where licensed operators are on duty at all times. There is a total of 270 miles of electrical wire in the plant.

38. Transformers that step up the voltage going to the substation.

39. Substation located 70 feet from the reactor. This 345,000 volt transmission line connects with lines extending from Kansas City through eastern Nebraska and north to Minneapolis.

40-41. OPPD, in cooperation with the University Hospital, has installed special equipment for handling possible radioactive injury.

Supplemental Materials Guide

BOOKLET

U.S. Commercial Nuclear Power—Historical Perspective, Current Status, and Outlook, U.S. Department of Energy, March 1982.

MAGAZINE

EPRI Journal, Electric Power Research Institute, Volume 5, Number 5, June 1980.

Science, "France's All-out Nuclear Program Takes Shape," Vol. 209, August 22, 1980.

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Electricity from Nuclear Power, Atomic Industrial Forum, Inc., Washington, DC 1980.

Energy, Engineering Extension Service and the Energy Research and Development Center, University of Nebraska-Lincoln, August, 1979.

Fusion, Washington, D.C.: Energy Research and Development Administration, 1977. **Nuclear Fusion—Factsheet #14,** Oak Ridge, Tennessee: DOE Technical Information Center, 1978.

Nuclear Power Information Fact Sheets, Atomic Industrial Forum, Inc., Washington, DC May, 1979.

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Lincoln, NE 68509

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Energy From the Atom